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INSTRUCTIONS FOR THE IRRADIATION OF SHEAR PINS FOR THE 76 MM PR--ETC(U)
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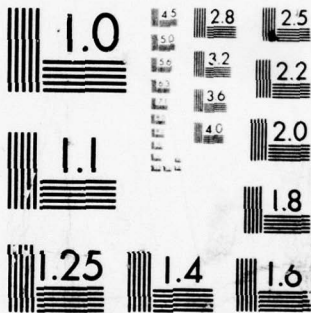UNCLASSIFIED NRL-MR-3789 SBIE-AD-E000 203 NL

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Instructions for the Irradiation
of Shear Pins for the 76 mm Primer

K. M. MURRAY

Radiation Effects Branch
Radiation Technology Division

LEVEL II

June 1978

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A procedure is given for irradiating shear pins used in the primer for 76 mm ammunition to produce the required amount of ^{22}Na activity in each pin. A method for monitoring the irradiation process is provided together with procedures to provide an absolute measurement of the amount of ^{22}Na produced in each pin.

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INSTRUCTIONS FOR THE IRRADIATION

OF SHEAR PINS FOR THE 76 mm PRIMER

BACKGROUND

A method was developed at NRL to determine the presence of a small aluminum shear pin in the primer of 76 mm Naval ammunition wherein the shear pin was made radioactive through the $^{27}Al(\gamma,\alpha n)^{22}Na$ reaction.[1-3] The final phase of that development program required the preparation of an "Ordnance Document" providing detailed step by step procedures for producing the required amount of ^{22}Na activity in each shear pin.

The following is the draft of that document which was submitted to the Naval Surface Weapons Center, Dahlgren Laboratory, Dahlgren, Virginia.

1. **PREAMBLE**

1.1   Purpose - These ordnance data describe the procedures to be followed
to irradiate the shear pin used in the primer for 76 mm ammunition.

1.2   This document presumes the user to be familiar with the operation
of an electron accelerator and the procedures of gamma-ray spectrometry.

1.2.1   A minimum of a basic understanding of nuclear physics at the
graduate level is required to carry out the procedures described in
this document.

2.0   **APPLICABLE DOCUMENTS**

2.1   Specifications - The following specifications may be used for
reference information with this document. The procedure described in
this document is based on the shear pins being manufactured to the
specifications in effect at the time of preparation of this document.

NAVORD
Code Ident 10001

WS-16100C   Critical Item Product function specification.
                   Primer, Percussion, MD161, Mod 0

FEDERAL
Tariff Number 30   Hazardous Materials, Regulations of the Department
                   of Transportation, Part 173.389 through .399

2.2   Drawings

NAVORD
Code Ident 10001
Drawing No. 3028557 Pin, shear

3.0   **COMPONENTS REQUIRED**

3.1   Inert components - The inert component is a shear pin (drawing).

4.0   **IRRADIATION SOURCE**

4.1   Irradiation source - The irradiation source must consist of an
electron accelerator and x-ray converter.

Note: Manuscript submitted May 18, 1978.

1

4.1.1   The rate of production of activity in the shear pins depends
          on the average beam current from the accelerator and on the beam
          energy.

4.1.2   The threshold for producing ^{22}Na is 22.5 MeV however there is very
          little yield below 35 MeV. (Accelerators which produce beam currents
          less than 100 microamperes and energies less than 30 MeV will require
          such long irradiation times that they will not generally be useful
          for the purpose of this document.)

4.2   X-ray converter - An x-ray converter system is required to produce
          high energy x-rays from the electron beam.

4.2.1   The converter system must be thick enough not to allow any of
          the electrons of the primary beam to hit the shear pins being
          irradiated as this would excessively heat them.

4.3   Measurement of the irradiation beam pattern
          The ^{12}C$(\gamma,n)^{11}$C reaction leading to a positron decay with half-
          life of 20 min. is used to measure the useful part of the x-ray beam.
          (This reaction has a threshold of 18 MeV.)

4.3.1.1   Pieces of polyethylene or graphite with an area of 1 cm^2 and a
          2 mm thickness will serve the purpose of this measurement.

4.3.1.2   The pieces are placed in three plane arrays. The pieces are
          arranged in the form of a cross with each leg containing 5 pieces
          spaced 1 cm apart.

4.3.1.3   These plane arrays of pieces are centered on, and perpendicular
          to, the beam axis at distances of about 10 cm, 20 cm, and 40 cm from
          the converter.

2

4.3.1.4   Distances along the beam axis from the converter must be measured from the surface of high-Z material in the converter which is hit first by the electron beam.

4.3.2   The three plane arrays of pieces are then irradiated for 1 hour using the same beam energy and current intended for the subsequent shear pin irradiation.

4.3.2.1   The exact time at which the irradiation ceased is noted.

4.3.3   The activity level of each piece is then measured using a Gieger or ion chamber type rate meter.

4.3.3.1   The exact time since the irradiation ceased is noted and the measured rate is corrected for the 20 min. half-life back to T_o, the time the irradiation ceased.

4.3.3.2   This correction is made according to the formula;

$$R_o = R_t \exp 0.034t,$$

where R_o is the rate at the time irradiation ceased, R_t is the rate measured at the time, t, in minutes after irradiation ceased.

4.3.3.3   The values of R_o are recorded for each piece on each array.

4.3.4   The beam pattern.

4.3.4.1   The average radius perpendicular to the beam axis at which the rate R_o is half the maximum observed on that array is determined for each array.

4.3.4.2   A graph of radius to half maximum vs. distance from the x-ray converter is drawn.

3

4.3.4.3   A graph of the maximum of each array vs. distance is drawn.

5.0   THE IRRADIATION CONTAINER

5.1   Irradiation container configuration - The irradiation container must be a right circular cylindrical cup made from aluminum.

5.1.1   The container must be rotatable about its cylindrical axis.

5.1.2   The container wall thickness should be about 1 mm.

5.1.3   The container internal dimensions must be such that randomly stacked shear pins will load it to a depth approximately equal to the internal diameter of the container.

5.1.4   The irradiation container must be rotated about a vertical axis during irradiation at a rate of about 1 revolution per minute.

5.1.5   The container is connected to the motor providing rotation by a shaft whose length is sufficient to prevent any serious radiation damage to the motor and rigid enough that the container will have less than 1/8" wobble during normal operation.

5.2   Loading of the irradiation container

5.2.1   Nine reference packages of 10 shear pins each are made up by wrapping in aluminum foil.

FOIL

10 SHEAR-PINS

4
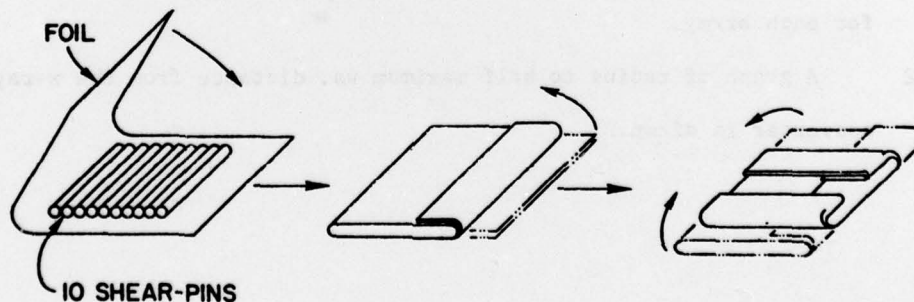
5.2.1.1   Three triple packs of three reference packages each are made
up using aluminum foil.
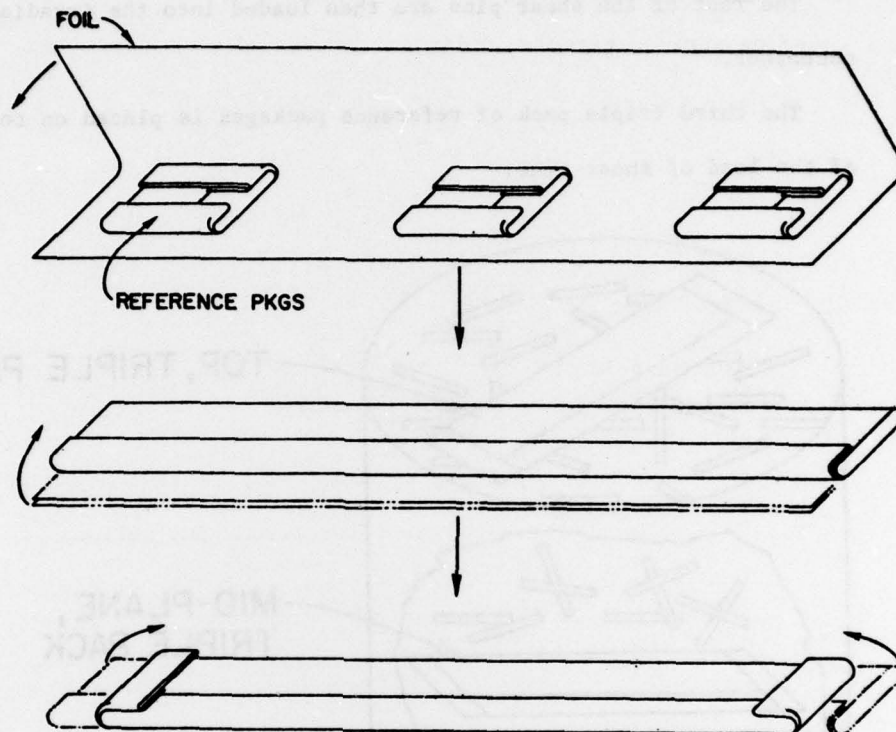
5.2.1.2   The dimensions of the triple pack are such that when placed
across the inner diameter of the irradiation container there will
be one package of 10 pins at the center and a package at each end
near the periphery.

5.2.2   First a triple pack of reference packages is placed across the
bottom of the container.

5.2.3   Next half of the shear pins to be irradiated are loaded on top
of the first triple pack.

5

5.2.4   A second triple pack of reference packages is placed on top
of the half load of shear pins.

5.2.5   The rest of the shear pins are then loaded into the irradiation
container.

5.2.6   The third triple pack of reference packages is placed on top
of the load of shear pins.

TOP, TRIPLE PACK

MID-PLANE,
TRIPLE PACK

FILLED WITH
SHEAR-PINS

BOTTOM,
TRIPLE PACK
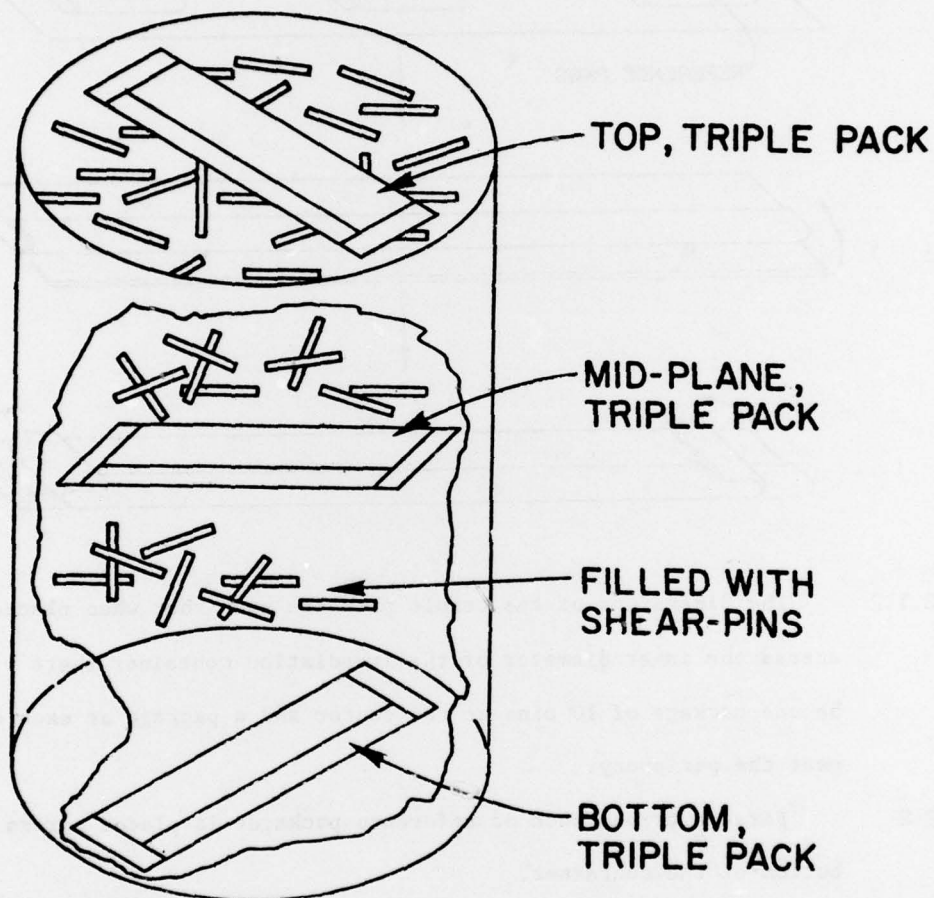
5.2.7   Three or four standard carbon samples wrapped in aluminum foil
are placed on top of the load near the center. (These will be used
to monitor the progress of the irradiation.)

6

5.3   Positioning of the irradiation container

5.3.1   To minimize the time required for irradiation the container
must be as close to the x-ray converter as possible commensurate
with the requirement of uniformity of irradiation.

5.3.1.1   The loaded irradiation container is placed at the distance where
all pins will be exposed to x-rays whose intensity is at least
half the maximum x-ray intensity seen by any of the pins.

5.3.1.2   This distance is determined from the data taken in section 4.3.

6.0   MONITORING OF THE IRRADIATION PROCESS

6.1   Facility monitors - It is assumed that all electron accelerator
facilities provide their own beam monitoring equipment.

6.1.1   The beam monitoring equipment must provide a means of insuring
that the following beam parameters remain stable or reproducible
during the irradiation period.

6.1.1.1   The beam energy should not vary by more than a few percent.

6.1.1.2   The beam current actually incident upon the converter should be
integrated during the irradiation period.

6.1.1.3   The focus of the beam on the converter should not change the
spot diameter by more than 25% during the irradiation.

6.2   Shear pin monitoring - The activity level of the shear pins is
monitored as follows.

6.2.1   Before starting irradiation an initial estimate of the total
irradiation time is made. (See Appendix A.)

6.2.2   At 10 to 15 percent of the estimated total irradiation time a
carbon monitor sample is removed from the top of the irradiation
container and its absolute [7]Be activity in nanocuries per gram of
carbon is determined after a cooling period of 4 hours or more.

6.2.3   The shear pin activity in nanocuries per shear pin is determined
          from the relation:

          shear pin activity = $(7.7 \times 10^{-3} \pm 15\%)$ x carbon activity in
          nanocuries per gram.

6.2.3.1   A new estimate of irradiation time is made based on the above
          measurement.

6.2.4   At from 50 to 60 percent of the revised estimate another carbon
          monitor is removed and counted.

6.2.4.1   A new estimate of total irradiation time is then made as in 6.2.2
          through 6.2.3.1 and the activation run is carried to completion based
          upon this estimate.

6.2.5   If for some reason an accurate prediction of completion time
          cannot be predicted based on the measurement at 50% another carbon
          monitor may be measured at some later time and a termination time
          estimated on the total of knowledge extant at that time.

7.0   SHORT LIVED RADIOACTIVITY

7.1   <u>Cool down of short lived radioactivity</u> - Immediately upon completion
          of the irradiation of the batch of shear pins they will be intensively
          radioactive.

7.1.1   The intensity of radiation emanating from the batch of shear
          pins will depend somewhat on the size of the batch, being over 10 R/hr
          at the surface for batches of 10,000 or more shear pins.

7.1.2   This radioactivity is due to a number of irradiation products whose
          half lives range from a couple of minutes to 13 hours.

8

7.2   Storage - The batch of shear pins must be stored in an adequately

        shielded place for from 10 to 14 days after irradiation before the

        reference packages are read to determine the absolute level of ^{22}Na

        in each shear pin.

8.0   ABSOLUTE DETERMINATION OF ^{22}Na CONTENT

        Standard source - The absolute determination of the ^{22}Na content

        of the shear pins requires a gamma-ray spectrometry system and a

        National Bureau of Standards (NBS) calibrated ^{22}Na source.

8.2   Gamma-ray spectrometer - A gamma-ray spectrometer is set up to

        read the total number of counts (peak plus background) in the 1.2745

        MeV full energy peak from ^{22}Na source and the total number of counts

        in an equal width region (for background) just on the high energy

        side of the 1.2745 MeV peak.

8.3   Counting geometry - The NBS calibrated source is then counted

        in the same geometry as the shear pins are to be counted.

8.3.1   In general the NBS source will be about 100 times as active as

        a shear pin.

8.3.2   The NBS source is counted for a particular live time sufficient

        to produce at least 1000 counts in the peak plus background region.

8.3.3   The number of counts in the region above the peak is subtracted

        from the number of counts in the region containing the peak to give

        the net number of counts in the 1.2745 MeV peak.

8.3.4   The net number of counts in the peak is divided by the live

        time to give the net count rate in counts per second.

8.3.5   The net count rate is then divided by the activity of the NBS

        source in curies at the time of the count of 8.3.2 to give the

        absolute counting efficiency for ^{22}Na of the system in net counts

        per sec. in the 1.2745 MeV peak per curie of ^{22}Na present in the sample.

9

8.3.5.1   The activity of the source at the time of 8.3.2 is given by:

$$S_T = S_o \exp(-0.266 \, \Delta T),$$

where S_T is the present activity, S_o is the activity at the calibration
date (provided with the source by NBS), and ΔT is the difference in
time between the calibration date and the date and time of 8.3.2
in units of years.

8.4   Counting the reference packages of shear pins

8.4.1   The reference packages of shear pins described in 5.2 are carefully
removed from the irradiation container keeping track of the location
of each package so that an accurate record of activity level throughout
the volume of the irradiation container may be determined.

8.4.1.1   The aluminum foil wrapping of each package of 10 shear pins must
be removed and discarded as radiation waste and the 10 shear pins
repackaged for counting in some unirradiated material. (Clear
sticky tape is quite suitable for this purpose.)

8.4.1.2   Ten shear pins from a single reference package are counted
together at the same location as the NBS standard was counted.
(See 8.3.)

8.4.1.3   Each group of 10 shear pins are counted for a live time sufficient
to give at least 1000 counts in the 1.2745 MeV full energy peak.

8.4.1.4   The net count rate for the 1.2745 MeV peak from the 10 shear pins
is determined in the same way as in 8.3.3 through 8.3.4.

8.4.1.5   The net count rate for the 10 shear pins is then divided by the
absolute counting efficiency (8.3.5) and also divided by 10 to give
The average activity of the shear pins in that particular package
in Curies of ^{22}Na per pin.

10

8.4.2   The procedure 8.4.1 through 8.4.1.5 is carried out for each of the nine reference packages to provide the distribution of activity throughout the irradiation volume.

8.5   <u>Documentation</u> - Complete documentation of the procedures and results described in 8 must be provided to the supplier of the shear pins.

9.0   <u>PREPARATION FOR DELIVERY</u>

9.1   <u>Packaging and labeling</u>

9.1.1   The shear pins will be packaged for shipping in accordance with the regulations cited in 2.1.

REFERENCES

1. K. M. Murray, NRL Report of Progress, March 1974.

2. Assembly Procedures for Percussion Primer EX161 Mod 0, NAVORD OD 46846.

3. K. M. Murray, NRL Memorandum Report 2887, September 1974.

Appendix

Estimating the Time Required
to Activate Shear Pins

The yield of ^{22}Na from bombarding aluminum with high energy photons has been measured at the U. S. Naval Research Laboratory. The results of that study are shown in the figure below.
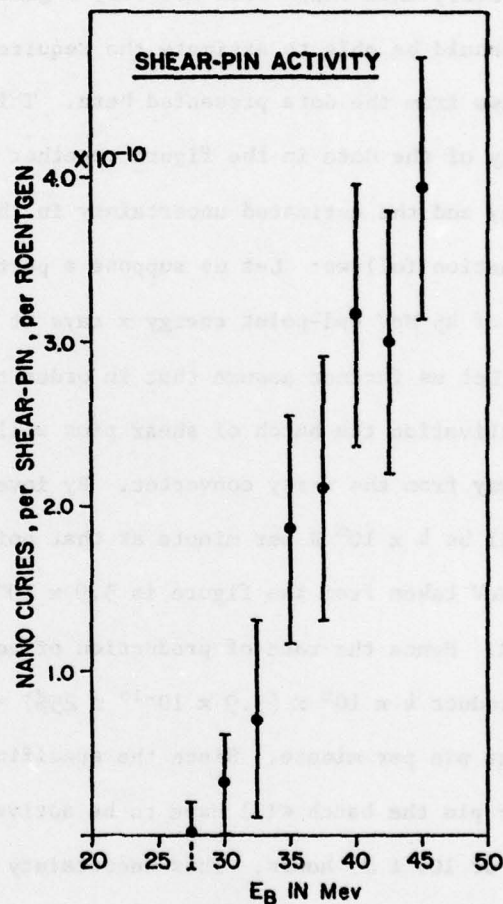

SHEAR-PIN ACTIVITY

Figure title: Shear pin activity in nanocuries per shear pin per Roentgen of x rays of end-point energy E_B.

13

The output of most high energy x-ray facilities is generally stated in terms of exposure dose rate, i.e., so many Roentgen (R) per minute at some point. The yield of ^{22}Na has therefore been stated in nanocuries of ^{22}Na per shear pin per Roentgen of x-rays of end-point energy E_B. These units were deemed most convenient for estimating the time required for producing the desired amount of activity in a batch of shear pins.

The actual production of activity will depend on the shape of the x-ray spectrum; however, this shape will not vary a great deal from facility to facility. One should be able to estimate the required activation time to within a factor of two from the data presented here. This uncertainty is based upon the uncertainty of the data in the figure together with its strong dependence on energy and the estimated uncertainty in the x-ray spectrum.

A sample estimation follows: Let us suppose a particular linac produces 10^5 (R) per minute of 45 MeV end-point energy x rays at 1 meter from its converter target. Let us further assume that in order to meet the requirements of uniformity of activation the batch of shear pins will have to be irradiated at a point 50 cm away from the x-ray converter. By inverse square law the x-ray intensity will be 4×10^5 R per minute at that point. The rate of activation for 45 MeV taken from the figure is $3.9 \times 10^{-10} \pm 25\%$ nanocuries per shear pin per R. Hence the rate of production of activity by the linac beam will be the product $4 \times 10^5 \times (3.9 \times 10^{-10} \pm 25\%) = 1.6 \times 10^{-4} \pm 25\%$ nanocuries per shear pin per minute. Since the specifications call for 1 nanocurie per shear pin the batch will have to be activated for $1/1.6 \times 10^{-4} = 6250 \pm 25\%$ minutes or 104 ± 26 hours. This uncertainty is from the figure only. It should at least be doubled to allow for uncertainties in the x-ray spectrum.

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Some facilities have calibrated their x-ray output in rads. One may convert Roentgens to rads by the following relationship.

air dose in rads = 0.87 x dose in Roentgens

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